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Studies on Strength of Netting (3)

Joint Strength of Twisted-Jointed Netting*

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그물감의 强度에 관한 硏究 (3)

貫通型 그물감의 마디의 强度

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관통형 그물감의 강도를 추정하기 위한 기초로서, 그물실의 강도가 관통마디에서 감소하는 기구 및 주름을 주었을 때의 관통마디의 강도를 조사하고, 이들 강도를 매듭의 강도와 비교하였다.

실험에는 vinylidene(mono-f.), polyester(multi-f.) 및 nylon(multi-f. 와 spun) 그물감이 사용되었으며, 관통마디의 시료는 이들 그물감을 재단하여 준비하였고, 또한 매듭은 이들 그물감의 다리로 만들어졌다.

실험 결과, 그물실의 강도가 관통마디에서 감소하는 원인은 마디에서의 편자사간의 마찰력으로 인해 마디의 첨단, 즉 마디와 다리와의 경계에 위치한 섬유들이 장력에 의해서 재분포하는데 마찰력만큼 저항을 받게 되고, 따라서 마찰력만큼 강도가 감소하는 것이라고 해석되었다. 그러나, 그 감소의 정도는 filament 그물실의 경우 5% 이내이고, spun 그물실의 경우는 5～10% 정도여서, 마디의 강도는 근사적으로는 그물실의 강도로 표시해도 좋을 것 같았다.

주름을 주었을 때의 관통마디의 강도는 인접하는 두개의 다리가 이루는 각 φ가 90°에서 최소치를 가지는 포물선상에서 변화하는 경향이었지만, 그 최소치는 강도의 감소가 가장 큰 濕막의 spun 실에서 φ가 0°때의 강도의 약 94%이어서, filament 그물실의 관통마디의 강도는 φ의 변화에 관계없이 거의 일정하다고 간주해도 좋을 것으로 추찰되었다. 따라서, filament 그물실의 관통마디의 강도는 주름을 준 경우이거나 안준 경우거나를 불문하고, 그물실의 강도로 표시해도 좋을 것 같았다.

관통마디의 강도를 매듭의 강도와 비교한 결과, 매듭의 강도는 관통마디의 강도의 약 70±5%로 나타났다.

INTRODUCTION

Knotless nettings are of increasing importance for fishing, especially in respects that they have no knots which are generally regarded to have low tensile strength [1)-7)], less resistance to water flow[8)], good resistance to abrasion[9)], etc. There were three types of knotless nettings of which joints were made by twisting the plied yarns of two twines once or several times, i. e., the twisted-jointed, the plover-jointed, and the turtleback-jointed netting. The plover-jointed and turtleback-jointed nettings were discovered through experiences in fishing to have insufficient strength as well as difficulties in using and used no longer. On the other hand, the twisted-jointed netting was surmised to be surperior to the knotted netting from its construction, and has replaced the knotted netting in almost every fishing gear. However, no experiments have yet been made which deal with the tensile strength of the twisted-jointed

* Twisted joint: Apex of meshes in twisted-jointed netting.

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netting in order to offer the data for the design of fishing gears with the netting.

In this study, the decrease in strength of netting twines at the joints of the twisted-jointed netting and the joint strength of the netting with bars opened were investigated. Furthermore, this joint strength was compared with the knot strength.

MATERIALS AND METHODS

The construction of twisted-jointed netting is shown in Fig. 1, and its materials used in this experiment in Table 1. Test pieces of twisted joints, each one joint and four bars, were prepared by cutting the netting. Reef knots and trawler knots to compare with twisted joints in strength were tied with bars of the netting. The testing machine, apparatus and methods employed have been described in the previous papers[6),7)] Figl.

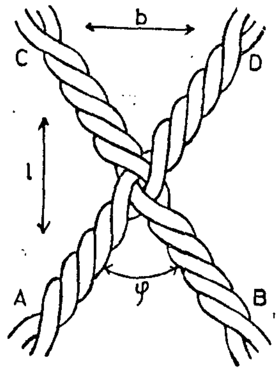

Fig. 1. Construction of twisted-jointed netting.
l: Lengthwise pull.
b: Breadthwise pull.
φ: Angle between adjacent bars.
A, *B*, *C*, *D*: Symbols of bars.

RESULTS AND DISCUSSION

1. Decrease in strength of netting twines at the twisted joint

In order to investingate the factors influencing the decrease in strength of netting twines at the twisted joint, the tensile strength of two bars, *A-D* or *B-C* in Fig. 1, running diagonally was tested in two cases; two bars being taken out of the other two bars to test and four bars being in the original twisted state. The tensile strength of the two bars in the latter cases was compared in *g/tex* with that of the twisted joint pulled simultaneously by four bars. The results are summarized in Table 1, in which T^0 stands for the tensile strength of bars or *straight* netting twines. In the case of two bar pull, no difference in strength seems to be made betweem the above two cases. This indicates that the two bars not pulled have no influence on the tensile strength of the other two bars pulled. However, the comparison in strength between the two bar pull and the four bar pull reveals differences. This means that netting twines at the twisted joint compress against each other by being pulled and are decreasing strength by the compression.

Table 1. Netting materials used in the experiment and their strength in *g/tex*

Materials	Dyeing	T^0		$T^b{}_{*1}$	T^t			
				dra	Dry		Wet	
					l *2	*b* *2	*l*	*b*
Vinylidene (mono-f.) 20 tex 16×2	black	10.2	10.5	10.2	9.6	9.5	9.8	9.9
Polyester (multi-f.) 28 tex 18×2	black	37.7	38.0	37.6	37.0	37.0	37.3	37.5
Nylon (multi-f.) 23 tex 15×2	black	51.7	—	51.6	51.5	51.7	—	—
Nylon (multi-f.) 23 tex 18×2	black	46.5	—	46.4	46.4	46.3	—	—
Nylon (spun) 59 tex 8×2	tar	27.8	25.5	27.8	26.5	26.2	24.8	23.2

* 1. Strength in A-D or B-C bar pull
* 2. Shown in Fig. 1

According to direct observation of the breakage of netting twines in the above experiments, the breakage in two bar pull occurred generally at the clamps which grip test pieces, but in four bar pull at the tips of the twisted joint, i.e., at the boundaries between the joint and the bars. More strictly, in case of four bar pull one of two plied yarns constructing a netting twine broke neatly as though it was cut with a knife, and the other in a disorderly way. The neat breakage also indicates that the tensile strength of netting twines at the twisted joint is influenced by the compression between them. Consequently, it seems that the decrease in strength of netting twines at the twisted joint is why by the compression between their plied yarns the fibres at the tips are subjected to a force.

Table 2. Approximate valnes of μ, s, ρ and α

	μ *1		s	ρ *2	α
	Dry	Wet			
Vinylidene 20 tex 16×2	0.28	0.30			
Polyester 28 tex 18×2	0.22	0.25			
Nylon 23 tex 15×2	0.24	0.27	πr *3	$4r$	$\frac{\pi}{4}$
Nylon 23 tex 18×2	0.24	0.27			
Nylon 59 tex 8×2	0.68	0.76			

* 1. Represented by the coeffioient of friction between netting twines.
* 2. Obtained from $\rho=2r/\cos^2\alpha$, assuming that plied yarns at that plied yarns at the twisted joint describe a helix.
* 3. Radius of plied yarns.

The force is considered to be the frictional force exerted on the fibres when they are compressed in course of redistribution by tensile loads. The frictional force will resist the redistridution of fibres as much as the given force and the tension in the fibres will increase as much as the resistance. Hence, the tensile strength of netting twines at the tips will decrease as much as the frictional force.

The frictional force F' acting on a plied yarn at the tips may be given by

$$F'=\mu\frac{s}{\rho}T', \qquad \cdots\cdots(1)$$

where μ is the coefficient of friction between plied yarns, s the contact length between the plied yarn at the tip and the other plied yarn compressing it, ρ the radius of curvature of the compressing, and T' the tension in the compressing.

If α is the angle between the plied yarn axis and the line perpendicular to the netting twine axis, the tension T' will be of the form;

$$T'=\frac{T^{t}}{2\sin\alpha}, \qquad \cdots\cdots(2)$$

where T^{t} is the tension in the bars or the twisted joint strength in case of joint breakage. Substituting Equation (2) in (1), F' becomes

$$F'=\mu\frac{s}{2\rho\sin\alpha}T^{t}, \qquad \cdots\cdots(3)$$

The frictional force F acting on a netting twine is written as

$$F=\mu\frac{s}{\rho\sin\alpha}T^{t}, \qquad \cdots\cdots(4)$$

However, the frictional force between plied yarns occurres not only at the twisted joint, but also at the bars. Moreover, the plied yarns at the twisted joint are compressed in a almost stanionary state. These facts give that not all of the compressional force P can be contributed to produce the frictional force F and that the frictional force influencing the decrease in strength should be given by means of AF, where A is a constant probably between O and 1.

Therefore, the tensile strength of netting twines at the twisted joint or the twisted joint strength T^{t} may be expressed as

$$T^{t}=T^{0}-AF \qquad \cdots\cdots(5)$$

of

$$T' = \frac{T^0}{1 + A\,\frac{s}{\rho}\,cosec\ \alpha}\ , \quad \cdots\cdots\cdots\cdots\cdots(6)$$

The value of A is difficult to determine theoretically, although suggested to be about 0.07 by substituting the values of T^0, μ, s, ρ, α and T' listed in Table 1 and 2 into Equation (6). In this study, therefore, the comparison of T' between its calculated and experimental values was not conducted. However, from Table 1 and 2 it can be seen that netting twines of larger value of $\mu\ \frac{s}{\rho} cosec\ \alpha$ show smaller value of T'. This comfirms that the decrease in strength of netting twines at the twisted joint is influenced by the factors given in Equation (6).

Table 1 indicates that the rate of decrease in strength of netting twines at the twisted joint is within 5% in filament twines and 5 to 10% in spun twines, showing no difference between the lengthwise and breadthwise pulls. These small rates give that the twisted joint strength in the pulls may be represented approximately by the tensile strength of straight netting twines. This approximation is more emphasized in case of filament twines. The more decrease in spun twines seems to be due to the larger coefficient of friction in them. The fixed decrease in the two pulls is considered to be attributed to the fixed valves of s, ρ and α in the two pulls, and to no technical difference in netting-making between the two directions. But in case of spun twines the more decrease in the breadthwise pull is considered to be due to the tear in the pull of fibres adhered to the lengthwise direction by tar-dyeing.

Netting twines used in this experiment were arranged in order of the twisted joint strength in *g/tex* as follows: Nylon>Polyester>spun Nylon>Vinylidene. When twisted joints were immersed in water, their strength increased a little in case of Polyester and Vinylidene, but decreased in case of Nylon. These were so with the bars (Table 1).

These results demonstrate that the properties in strength of the twisted joint may be represeented approximately by those of straight netting twines.

2. Twisted joint strength in pull by opened bars

As mentioned above, the apparatus used to test the twisted joint strength in pull by opened bars has been described in the previous paper[7]. In using the apparatus filament twines broke mostly at the clamps, but several of them broken at the twisted joint showed no remarkable difference in strength with those pulled by closed bars. These facts requested the test with filament twines unneccessary by reason of the negligible difference in strength, so that only the wet spun twines broken mostly at the twisted joint were adopted for the test.

Fig. 2 indicates the variation of the twisted joint strength T' of wet spun twines with the angle φ between the adjacent bars, *A-B* or *C-D*. The strength varies on a parabola having a minimum value, about 94% of the value at $\varphi=0°$, at $\varphi \fallingdotseq 110°$.

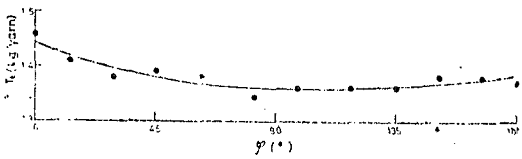

Fig. 2. Variation of twisted joint strength T' with φ. Material: Spun Nylon 59 tex 8×2.

The plied yarns at the twisted joint have fixed values of s, ρ and α through all values of φ so that the compressional force between them seems to keep at a uniform value through all values of φ. But the frictional force or the resistance to the redistribution of fibres seems to vary slightly with φ, and the increment of tension in the fibres at the twisted joint does so. That is, at $\varphi=0°$ or $\varphi=180°$ the plied yarns at the twisted joint run almost parallel to each other as at the bars and so the resistance to the redistribution of fibres at the tip will be relativery small as at the bars. As φ approaches

90°, the angle between two plied yarns compressing against each other also does 90° and the resistance will increase. Consequently, with varying φ from 0° or 180° to 90° the tension in the fibres at the tip will increase. Hence, the twisted joint strength will vary on a parabola having the minimum value at $\varphi=90°$, i.e., the relation of T' with φ may ae expressed as

$$T'=a(\varphi-90)^2+bT'^0, \quad \cdots\cdots(7)$$

where T'^0 is the value of T' at $\varphi=0°$, a and b being constants. However, the occurrance of the minimum value at $\varphi \fallingdotseq 110°$ in wet spun twines is probably why the fibres adhered to the lengthwise direction by tardyeing tear in pulls at φ from 90° to 180° and weaken the twisted joint strength at the angles. In the same twines the values of a and b were 0.007 and 0.94 respectively. These values indicate that the variation of T' with φ is considerably smooth. However, the variation of T' in filament twines is considered to be much more smooth than that in spun twines from their breakage and strength mentioned above. Therefore, the twisted joint strength of filament twines may be regarded to keep at a uniform value regardless of the variation of φ. Consequently, the twisted joint strength of filament twines may be represented approximately by the tensile strength of straight netting twines not only in the pull by closed bars but also in that by opened bars.

3. Compairson with knot strength

The relation of the twisted joint strength to the knot strength is shown in Fig. 3. Netting twines decrease in strength at the twisted joint less than 10% of their strength at the bars, but as much as 10 to 40% at the knot. The twisted joint shows no significant difference in strength between the lengthwise and breadthwise pulls, but the knot pulled breadthwise hase 6 to 20% more or less strength than that pulled lengthwise. General views give that the knot strength is about 35±5% of the twisted joint strength. These results demonstrate that the twisted joint is much more excellent in strength than the knot.

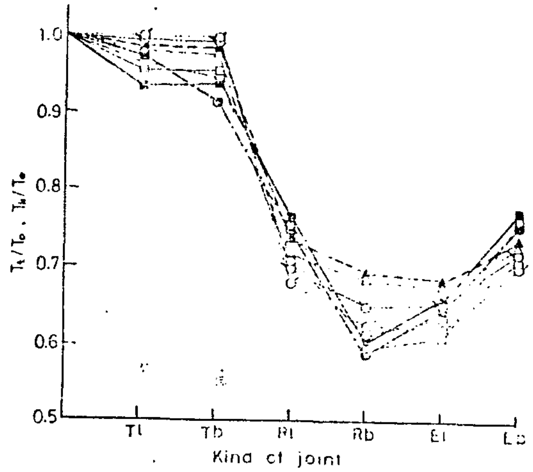

Fig. 3. Comparison of twisted joint strength T' with knot strength T^k.
Tl, *Tb*; Twisted joint.
Rl, *Rb*: Reef knot.
El, *Eb*: Trawler knot. (*l*, *b*: shown in Fig. 1).
——□: Vinylidene 20 tex 16×2 dry,
——▣: Vinylidene 20 tex 16×2 wet,
- - - -△: Polyester 28 tex 18×2 dry,
- - - -▲: Polyester 28 tex 18×2 wet,
········ ♂: Nylon 23 tex 15×2 dry,
—··—♭: Nylon 23 tex 18×2 dry,
—·—○: Spun Nylon 59 tex 8×2 dry,
—·—●: Spun Nylon 59 tex 8×2 wet.

When twisted joints and knot were immersed in water, they both increased a little in strength in case of Vinylidene and Polyester, but decreased a little in case of Nylon. These variation seem to be followed by the properties of fibre materials.

Fig. 4 shows the relation between the knot strength of dyed two-ply twines and that of non-dyed three-ply twines. There seems to be no remarkable difference in strength between the two kinds of knots, although a little difference in created in wet condition probably by the obstruction of dyed goods to the absorption of water by the twoply twines. Therefore, the comparison of the twisted joint strength with the knot strength of two-ply twines in that experiment may be regarded to be that with the knot strength of three-ply twines.

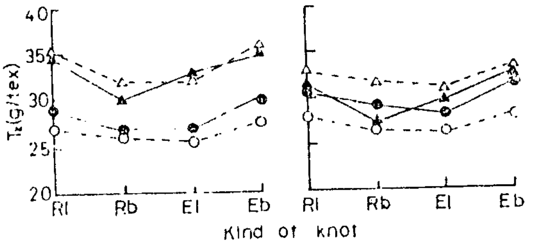

Fig. 4. Comparison of knot strength T^k two-ply and three-ply twines.
○: Polyester 28 tex 18×2,
●: Polyester 23 tex 12×3,
△: Nylon 23 tex 15×2,
▲: Nylon 23 tex 10×3.
Rl, Rb, El, Eb: Shown in Fig. 3.

SUMMARY

1) The decrease in strength of of netting twines at the twisted joint is regarded to be due mainly to the frictional force between plied yarns, but the rate of decresae is within 5% in filament twines and 5 to 10% in spun twines.

2) The variation of the twisted joint strength with the angle between the two adjacent bars draws a parabola having the minimum value at the angle of 90°. The minimum value was revealed as about 93% of the strength at the angle of 0° in wet spun twines, but regarded to be negligibly small in filament twines.

3) The knot strength is about 30±5% of the twisted joint strength.

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